Visual Inspection of Surfaces

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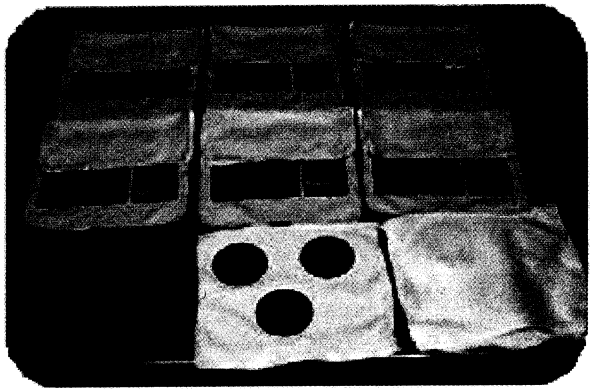
Experiment Purpose

- Evaluate the parameters that affect visual inspection of cleanliness
  - Current standards do not account for surface type, experience of inspector, etc
  - Result is that surfaces meeting the same standard level may have very different cleanliness

Experiment Design

- Factors tested
  - Surface reflectance
  - Surface roughness
  - Largest particle size
  - Exposure time
  - Inspector
- Measurement
  - Distance to sample

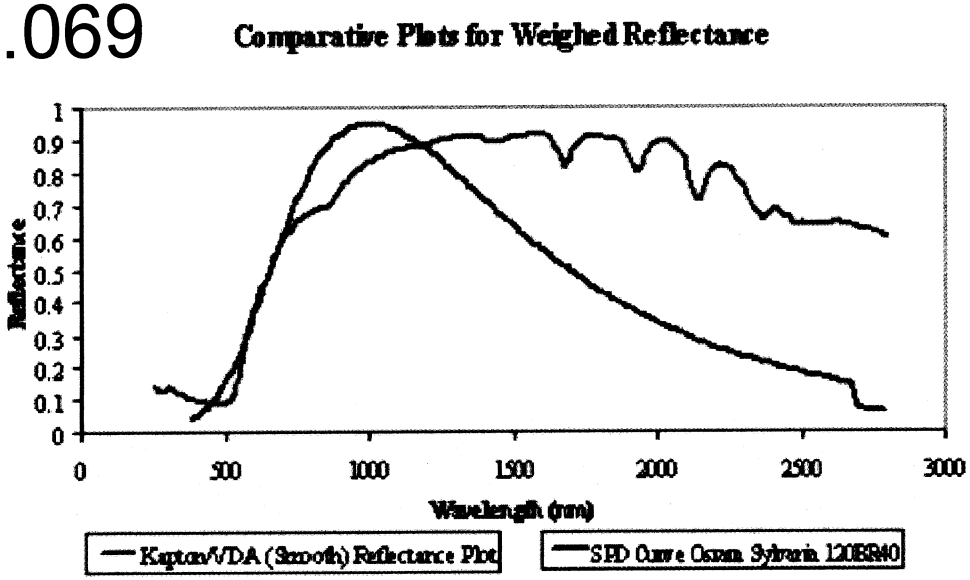


Reflectance Values

- Weighted by cleanroom lamp spectral power distribution

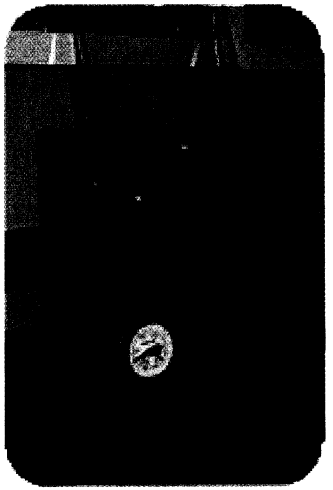
$$\rho = \frac{\int_{380}^{780} \rho(\lambda) \cdot s(\lambda) d\lambda}{\int_{380}^{780} s(\lambda) d\lambda}$$

- Three integrated reflectance values used
  - Black Kapton: 0.069
  - Kapton: 0.456
  - VDA: 0.889



Roughness Values

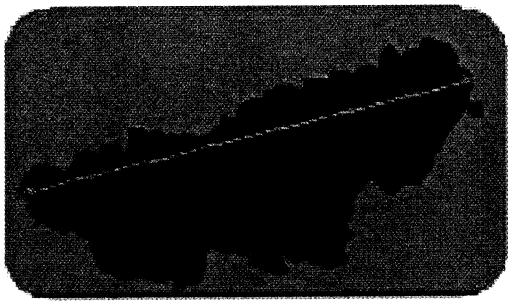
- Rough surface created by pressing sandpaper into film sample
  - Used 60 grit paper
  - 20 psi
  - Approx 270 micron particle size
  - Because of random particle orientation, spacing and depth of indents was irregular
  - Roughness assigned value of 0 for smooth or 1 for rough



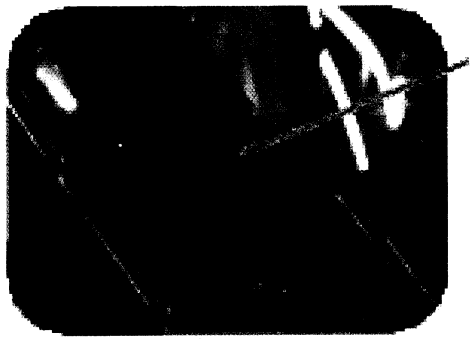
Carver Inc. Press Machine
Model 4350. L

Exposure and Particle Size

- Samples exposed to cleanroom fallout for 1-7 days before the visual inspection
- After the visual inspection, the largest particles were collected by tape lift and measured



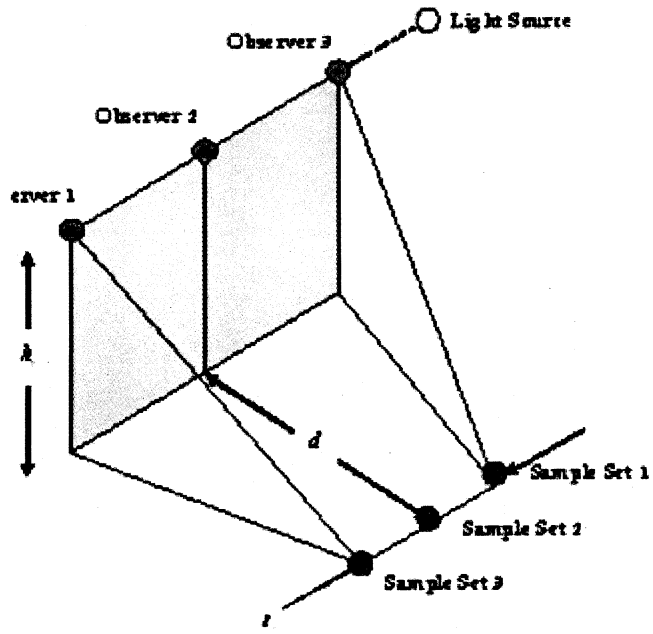
Feret of a Large Particle



Particle on a Smooth Black Kapton Sample

Test Setup

- Three observers in parallel
- Light behind and to the side of the observers
- Samples arranged in grid on table (random order)



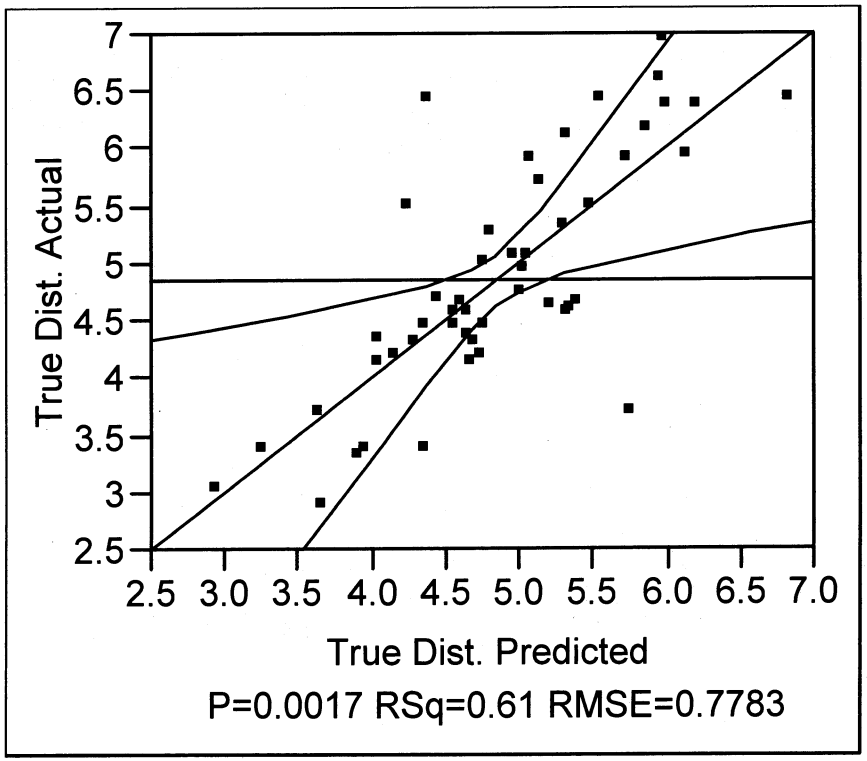
DOE Regression

- Fit up to fourth order interactions
  - Except observer; added interactions one at a time
  - Only first order effects from observer had any statistical significance
- Analysis of Variance
  - Model equation is statistically significant with 99% confidence

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	15	30.762221	2.05081	3.3859
Error	33	19.988016	0.60570	Prob > F
C. Total	48	50.750237		0.0017

Model Fit

- Distance predictions are not great
  - Distance at which contamination is seen may depend on more variables than those tested



Parameter Estimates

- Most parameter estimates have confidence of 95% or better
- Three exceptions (highlighted rows)

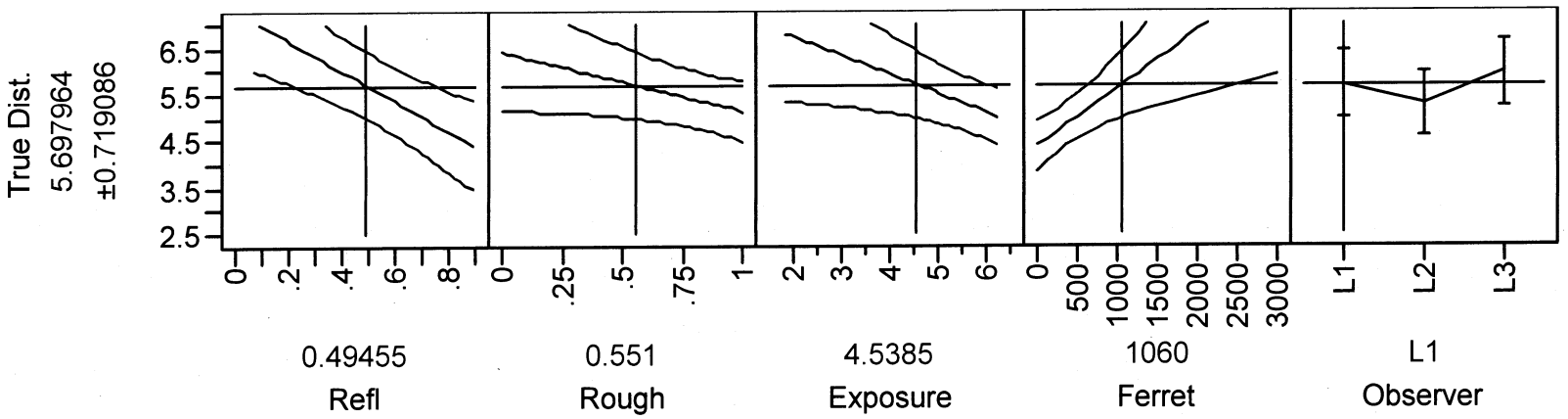
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	8.4987743	1.043563	8.14	<.0001
Refl	-3.251522	0.865699	-3.76	0.0007
Rough	-1.285622	0.648001	-1.98	0.0556
Exposure	-0.405207	0.166506	-2.43	0.0205
(Refl-0.49455)*(Exposure-4.53849)	3.1261103	0.727024	4.30	0.0001
(Rough-0.55102)*(Exposure-4.53849)	1.6810883	0.416319	4.04	0.0003
(Refl-0.49455)*(Rough-0.55102)*(Exposure-4.53849)	-3.622634	1.110143	-3.26	0.0026
Ferret	0.0012317	0.000398	3.10	0.0040
(Refl-0.49455)*(Ferret-1060)	-0.004593	0.001235	-3.72	0.0007
(Rough-0.55102)*(Ferret-1060)	-0.002424	0.000905	-2.68	0.0114
(Exposure-4.53849)*(Ferret-1060)	-0.000301	0.000254	-1.19	0.2440
(Refl-0.49455)*(Exposure-4.53849)*(Ferret-1060)	0.002217	0.000846	2.62	0.0132
(Rough-0.55102)*(Exposure-4.53849)*(Ferret-1060)	0.0010646	0.000442	2.41	0.0219
(Refl-0.49455)*(Rough-0.55102)*(Exposure-4.53849)*(Ferret-1060)	-0.00146	0.001253	-1.16	0.2524
Observer[L1]	0.0489993	0.159809	0.31	0.7611
Observer[L2]	-0.351511	0.159776	-2.20	0.0349

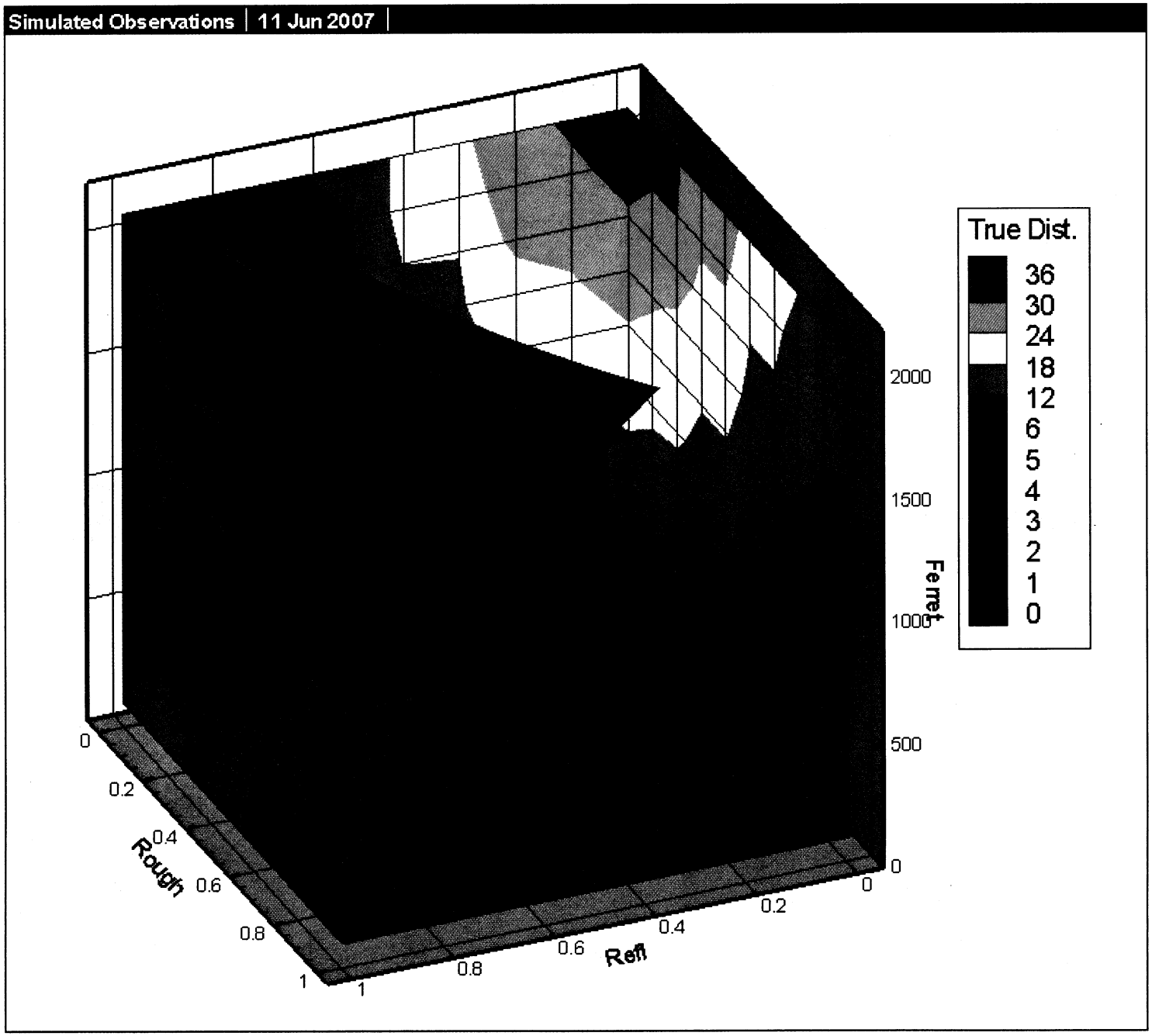
Model Equation

- 8.499 +
- -3.252 * Refl +
- -1.286 * Rough +
- -0.4052 * Exposure +
- 0.001232 * Ferret +
- (Refl - 0.4946) * (Exposure - 4.538) * (3.126) +
- (Rough - 0.5510) * (Exposure - 4.538) * (1.681) +
- (Refl - 0.4946) * (Rough - 0.5510) * (Exposure - 4.5385) *(-3.623) +
- (Refl - 0.4946) * (Ferret - 1060) * (-0.004593) +
- (Rough - 0.5510) * (Ferret - 1060) * (-0.002424) +
- (Exposure - 4.538) * (Ferret - 1060) * (-0.0003008) +
- (Refl - 0.4946) * (Exposure - 4.538) * (Ferret - 1060) * (0.002217) +
- (Rough - 0.5510) * (Exposure - 4.538) * (Ferret - 1060) * (0.001065) +
- (Refl - 0.4946) * (Rough - 0.5510) * (Exposure - 4.538) * (Ferret - 1060) * (-0.001440) +
- Match Observer("L1“: 0.04900, "L2“: -0.3515, "L3“: 0.3025)

Response to Variables

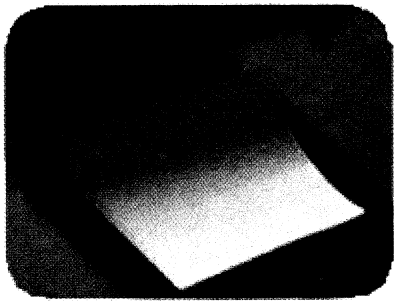
- Distance at which surface is visibly contaminated decreases with increasing
  - Reflectance, Roughness, Exposure (PAC)
- Increases with largest particle size
- Is only slightly affected by observer




Simulated Observations | 11 Jun 2007
True Dist.
36
30
24
18
12
6
5
4
3
2
1
0
2000
1500
1000
500
0
Feet
Rough
0
0.2
0.4
0.6
0.8
1
Refl
0
0.2
0.4
0.6
0.8
1

Discussion

- The light source and observation point was fixed relative to the sample
  - In an actual inspection, the light source is usually hand held, and the observer can move relative to the source
- Perceived roughness may trick the brain into discarding particles
  - Diffuse scatter from increased PAC may have the same effect
- Variability between observers was less than other effects
  - Experience did play a part in differentiating scratches from fibers



Curved VDA Sample

Glare was a significant factor for some samples